

ABSTRACT: GENESIS HALO ORBIT STATION KEEPING DESIGN

Kenneth Williams^{}, Roby Wilson and Martin Lo
Jet Propulsion Laboratory
California Institute of Technology
Pasadena CA 91109-8099*

*Kathleen Howell and Brian Barden
School of Aeronautics and Astronautics
Purdue University
West Lafayette, IN 47907-1282*

Genesis is the fifth mission selected as part of NASA's Discovery Program. The objective of Genesis is to collect solar wind samples for a period of approximately two years around the Earth-Sun L1 point. At the end of this period, the spacecraft follows a free-return trajectory with the samples delivered to a specific recovery point on the Earth for subsequent analysis. This goal has never been attempted before and presents a formidable challenge to terms of both mission design and operations.

An overview of the Genesis trajectory is shown in Figure 1. One unusual feature of this trajectory is that it requires only one deterministic maneuver, which inserts the spacecraft into the Lissajous or halo orbit at the end of the transfer from Earth to the Earth-Sun L1 region. Also, following completion of the halo orbit phase of the mission, the spacecraft automatically leaves the libration point region with no departure maneuver. This trajectory is the first to be designed using modern dynamical systems theory by a group consisting of two of the authors. Since that time, additional performance studies have been conducted to enhance various aspects of the mission design. One particular area of interest involves station keeping strategies for the four halo orbits, where the bulk of the solar wind collection is to be performed. One study, by two of the authors, determined that the best strategy for station keeping entails three maneuvers per orbit, approximately 60 days apart, with the first such station keeping maneuvers about two months after the Lissajous orbit insertion maneuver. Details from this and other early studies will be included in the paper.

In addition to orbit dynamics, there are a number of considerations arising from the spacecraft design itself. An overview of the spacecraft design, which will be explained in more detail in the paper, is shown in Figure 2. To achieve a level of cost-effectiveness consistent with a Discovery-class mission, the Genesis spacecraft design was adapted to the maximum extent possible from designs used on earlier missions, such as Mars Surveyor Program 98 and Stardust, another sample collection mission. Power is provided by solar arrays with a battery in reserve. To avoid battery power depletion, solar arrays are normally pointed to within 10° of the sun with a time limit of about 85 minutes when the spacecraft is more than 30° off sun. Spin stabilization was chosen as a simple means of attitude control, in lieu of three-axis stabilization, with no reaction wheels, gyros or accelerometers. Therefore, any attitude changes, including spin changes and precessions, must be performed in an open loop fashion with thrusters. Moreover, thrusters are located on the opposite side of the space vehicle from science instruments to minimize contamination of samples over the course of solar wind collection. Because the thrusters do not produce balanced torques, all attitude control maneuvers result in a translational Δv , affecting the spacecraft trajectory.

^{*}Additional information for corresponding author: Senior Engineer currently assigned to Genesis Project as Maneuver Design Analyst; address at JPL: 4800 Oak Grove Drive, M/S: 301-125; phone: (818) 393-5922, FAX: (818) 393-6388, e-mail: kenneth.e.williams@jpl.nasa.gov

A number of additional challenges have arisen as a result of emerging instrument design concerns and operational constraints. The primary science instrument, known as the concentrator, collects Nitrogen and Oxygen ions onto a target via electrostatic grids. If the concentrator is pointed more than 60° or so away from the sun when exposed to space, the grid becomes shaded introducing a large thermal gradient with respect to the container causing irreparable damage to the instrument. Therefore, as a primary means of avoiding excessive turns away from the sun, all station keeping maneuvers need to be biased towards the sun.

All of these factors complicate planning and execution of propulsive maneuvers, especially small station keeping maneuvers. However, recent monte-carlo studies by one of the authors have demonstrated that a combination of the strategy of three station keeping maneuvers per halo orbit with sunward biasing of 1.5 m/s per maneuver provides a feasible approach to meet mission objectives while satisfying spacecraft and instrument operational constraints. The paper will include results from these studies, as well as an approach for pursuing further studies of contingency scenarios which must be planned in response to potential operational anomalies.

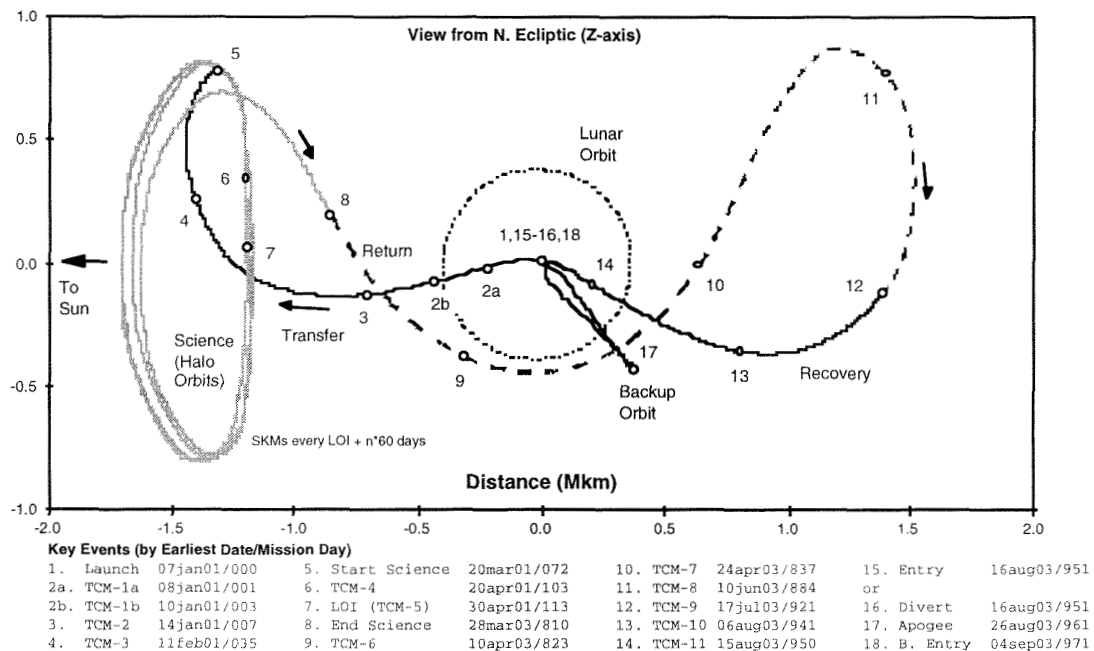


Figure 1. Genesis Mission Trajectory.

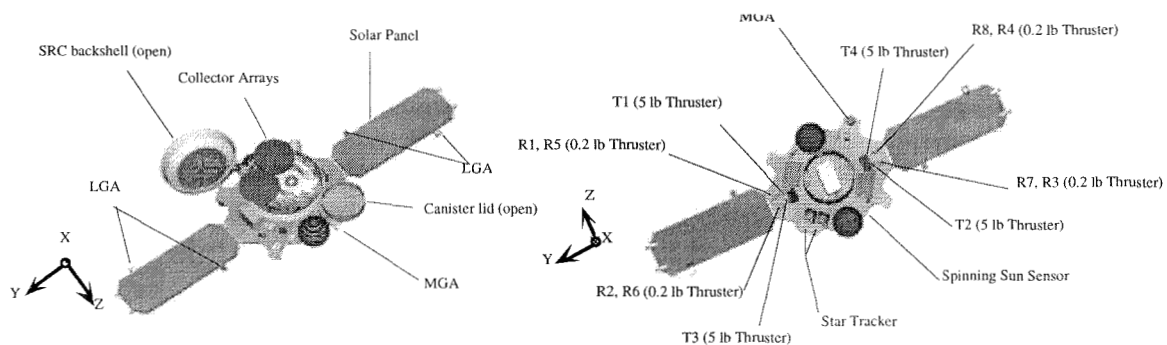


Figure 2. Forward Deck View (Normally Pointing Toward Sun) and Rear Deck View